The Distribution of Grammatical Information across Sets: Some Consequences for Coordination

PETER G PETERSON
University of Newcastle
LNPGP@alinga.newcastle.edu.au

1. Introduction

This paper presents an LFG-based analysis of coordination in terms of (non-headed) sets of f-structures and the distribution of grammatical functional information across sets. The analysis provides the basis for an explanation of a range of properties of coordination constructions, including referential identity, patterns of anaphora and control. Further, the condition that unlike categories can be conjoined if and only if they are eligible to serve the same grammatical function in the containing clause does not have to be stipulated but follows as an axiom from the general principles of functional application to sets.

The basic assumption on which the proposed analysis is built is stated in (1):

(1) The functional structure of a coordination of constituents is the set of functional structures of the coordinated elements.

Put very simply, (1) states that at the functional level of analysis coordination is a set.[1] As pointed out by Kaplan & Maxwell (1988: 304):

> Sets constitute a plausible formal representation for coordination since an unlimited number of items can be conjoined in a single construction and none of those items dominates or has scope over the others.

The annotated rule schema in (2) expresses this idea for English coordinate structures.[2]

(2) $X \rightarrow \underset{\downarrow \quad \uparrow}{X} \quad C \quad \underset{\downarrow \quad \uparrow}{Y}$

One important feature of this schema is that coordination is not a "headed" construction; it is not endocentric. Neither X nor Y on the right hand side of the schema is head, and therefore no grammatical information percolates upwards to the dominating node.

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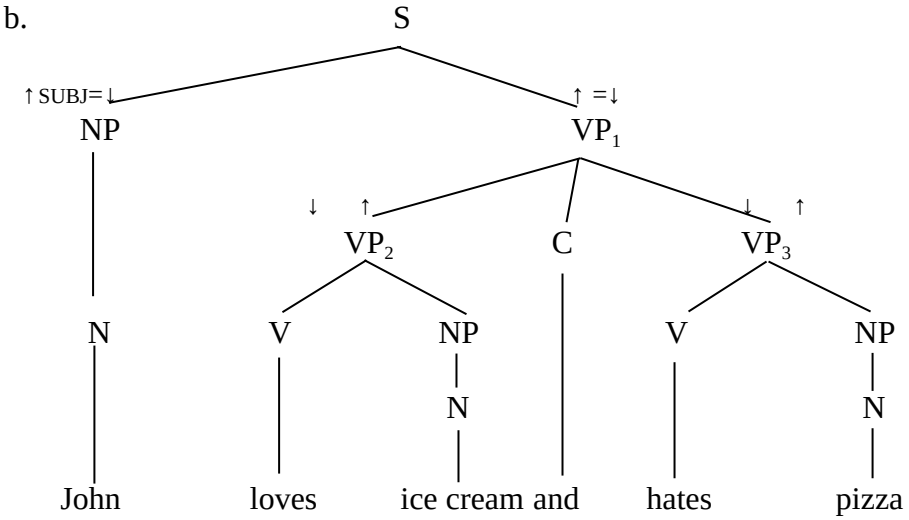
[1] Functional structures which consist of sets of functional structures are discussed in detail in Dalrymple & Kaplan (1997).

[2] The absence of functional notation on the coordinator in Schema (2) is not an oversight. I assume with Kaplan & Maxwell (1988: 305) that the coordinator is not assigned any functional role. In their words (loc. cit.) "the identity of the particular conjunction does not seem to enter into any syntactic or functional generalizations, and therefore […] there is no motivation for including it in the functional structure at all. Instead, it is necessary to encode this information only on the semantic level of representation […]."

The effect of schema (2) is illustrated by the structures in (3) and (4). (3b) is the partially annotated c-structure for the sentence (3a):

(3) a. John loves ice cream and hates pizza

b.



(4) a. functional structure of VP_1:

$$f_1 \left\{ \begin{array}{ll} f_2 & \left[\begin{array}{ll} \text{SUBJ} & — \\ \text{TENSE} & \text{PRES} \\ \text{PRED} & \text{‘love <}(f_2\ \text{SUBJ})\ (f_2\ \text{OBJ})\text{>’} \\ \text{OBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘ice cream’} \\ \text{NUM} & \text{SG} \end{array} \right] \end{array} \right] \\ f_3 & \left[\begin{array}{ll} \text{SUBJ} & — \\ \text{TENSE} & \text{PRES} \\ \text{PRED} & \text{‘hate <}(f_3\ \text{SUBJ})\ (f_3\ \text{OBJ})\text{>’} \\ \text{OBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘pizza’} \\ \text{NUM} & \text{SG} \end{array} \right] \end{array} \right] \end{array} \right\}$$

b. functional structure of S:

$$f_0 \left\{ f_1 \left\{ \begin{array}{ll} f_2 & \left[\begin{array}{ll} \text{SUBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘John’} \\ \text{NUM} & \text{SG} \end{array} \right] \\ \text{TENSE} & \text{PRES} \\ \text{PRED} & \text{‘love <}(f_2\ \text{SUBJ})\ (f_2\ \text{OBJ})\text{>’} \\ \text{OBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘ice cream’} \\ \text{NUM} & \text{SG} \end{array} \right] \end{array} \right] \\ f_3 & \left[\begin{array}{ll} \text{SUBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘John’} \\ \text{NUM} & \text{SG} \end{array} \right] \\ \text{TENSE} & \text{PRES} \\ \text{PRED} & \text{‘hate <}(f_3\ \text{SUBJ})\ (f_3\ \text{OBJ})\text{>’} \\ \text{OBJ} & \left[\begin{array}{ll} \text{PRED} & \text{‘pizza’} \\ \text{NUM} & \text{SG} \end{array} \right] \end{array} \right] \end{array} \right\} \right\}$$

(4a) is the f-structure for the coordinate VP (VP_1) *loves ice cream and hates pizza*, where f_2 is the f-structure of VP_2, f_3 is the f-structure of VP_3, and f_1 is the set consisting of $\{ f_2, f_3\}$. To complete the f-structure for the sentence as a whole, as shown in (4b), we have to establish the values for the SUBJ of each of f_2 and f_3. To do this, we need to extend the formal mechanism of LFG.

The basic descriptive mechanism underpinning the whole LFG formal system is the equation linking particular attributes within f-structures to particular values. In formal terms, the statement of function application in simple cases (following Kaplan & Bresnan (1982)) is as follows:

(5) (f a) = v if and only if: f is an f-structure, a is an attribute, v is a value, **and** (a v) f

To give a simple example, in (4b), (f_2 TENSE) = PRES because the pair (TENSE PRES) is contained within f_2. So we can say that "f_2's TENSE is PRES".

With coordination, the elements of a coordinate structure carry exactly those grammatical functions that they would have carried if they had appeared alone in place of the coordination. This means that grammatical function attributes need to be distributed across the elements of a coordinate structure, which in f-structure representation is an f-structure consisting of a set of f-structures. We therefore need to extend the function application statement in (5) to allow for the distribution of grammatical information (specifically, grammatical function attributes) into functional structures that are sets. We do this by adding a Part (b) to the function application statement, giving the following:

(6) (f a) = v if and only if: f is an f-structure, a is an attribute, v is a value, **and**
  (a) (a v) f ; **or**
  (b) S is a set of f-structures, G is a grammatical function attribute,
  and for all f S, (f G) = v

(6b) means that in a set of f-structures, if G has the value v in one f-structure it will have that value in all f-structures within the set. The effect of (6b) is to capture the notion that the value of any grammatical function within a set will distribute to all f-structures within the set. Therefore we can use this to assign values to the SUBJs of f_2 and f_3 in (4). We know from the c-structure (3b) that f_1 SUBJ = 'John'. Schema (6b) allows this value to be distributed to f_2 SUBJ and f_3 SUBJ, giving the completed f-structure shown in (4b).

2. Consequences of the distribution of grammatical functions

We can now explore some consequences of this simple extension to the LFG framework. It will become apparent that a number of properties of coordinate structures follow directly from adding (6b) to the theory of functional structure.

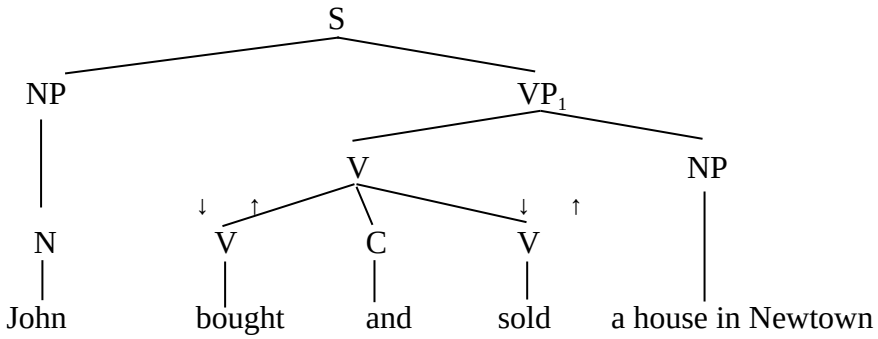
2.1 Referential identity

Consider first the contrast between the sentences in (7):

(7) a. John bought and sold a house in Newtown
  b. John bought a house in Newtown and John sold a house in Newtown

Whereas example (7a), with coordinate verbs, has the c-structure and f-structure shown in (8), example (7b), with coordinate sentences, has the c-structure and f-structure shown in (9):

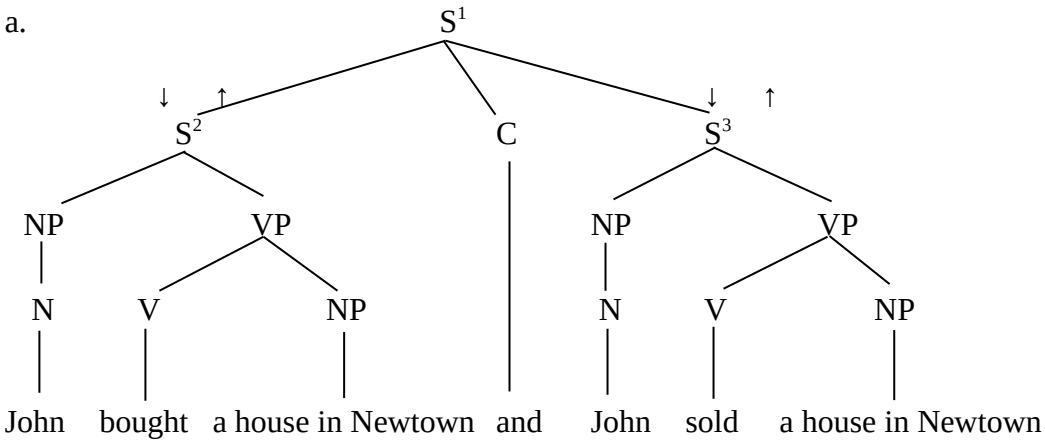
(8) a.



b.

$$f_1\left\{\begin{array}{l} f_2\left[\begin{array}{ll} \text{SUBJ} & f_5 \quad \text{PRED 'John'} \\ \text{TENSE} & \text{PAST} \\ \text{PRED} & \text{'buy <}(f_2\ \text{SUBJ})\ (f_2\ \text{OBJ})\text{>'} \\ \text{OBJ} & f_4\left[\begin{array}{l} \text{DEF} \quad - \\ \text{PRED 'house in Newtown'} \end{array}\right] \end{array}\right] \\ f_3\left[\begin{array}{ll} \text{SUBJ} & f_5 \\ \text{TENSE} & \text{PAST} \\ \text{PRED} & \text{'sell <}(f_3\ \text{SUBJ})\ (f_3\ \text{OBJ})\text{>'} \\ \text{OBJ} & f_4 \end{array}\right] \end{array}\right\}$$

(9) a.



b.

$$\left\{\begin{array}{l} \left[\begin{array}{ll} \text{SUBJ} & f_5 \quad \text{PRED 'John'} \\ \text{TENSE} & \text{PAST} \\ \text{PRED} & \text{'buy <}(f_2\ \text{SUBJ})\ (f_2\ \text{OBJ})\text{>'} \\ \text{OBJ} & f_4\left[\begin{array}{l} \text{DEF} \quad - \\ \text{PRED 'house in Newtown'} \end{array}\right] \end{array}\right] \\ \left[\begin{array}{ll} \text{SUBJ} & f_6 \quad \text{PRED 'John'} \\ \text{TENSE} & \text{PAST} \\ \text{PRED} & \text{'sell <}(f_3\ \text{SUBJ})\ (f_3\ \text{OBJ})\text{>'} \\ \text{OBJ} & f_7\left[\begin{array}{l} \text{DEF} \quad - \\ \text{PRED 'house in Newtown'} \end{array}\right] \end{array}\right] \end{array}\right\} \begin{array}{l} f_1 \\ f_2 \\ f_3 \end{array}$$

There is an important difference between the f-structures (8b) and (9b). In the latter, the OBJ within each conjunct is represented by a distinct f-structure (f_4 and f_7), while in the former the OBJ within each conjunct is represented by the same f-structure (f_4). Although the OBJ f-structures f_4 and f_7 in (9b) both happen to contain the same lexical contents, *a house in Newtown*, they represent different instantiations of the lexical features of *a house in Newtown*, corresponding to the different object NPs in the c-structure (9a). In contrast, in the c-structure (8a) there is only one object NP, and hence only one instantiation of features, distributed to the two conjunct f-structures by mechanism (6b).

This difference in f-structure has semantic consequences. The value of the PRED feature is a semantic form. Each instantiation of a semantic form creates a unique object for semantic interpretation (Kaplan & Bresnan 1982: 225) since it is functional structures that are semantically interpreted. Thus the two Objects in the f-structures of examples such as (7b) can be interpreted differently while the shared Object in examples like (7a) cannot be. This then gives a straightforward account of the interpretation that the same house is bought and sold in example (7a). Similarly, the same two reporters are involved in the two actions described in (10a), but not necessarily in (10b):

(10) a. Two reporters came up to John and asked him about his work.
b. Two reporters came up to John and two reporters asked him about his work.

These different readings follow naturally from the semantic interpretation of the different f-structures, and, contrary to the claims of Bach (1980) and Grimshaw (1992), do not require special syntactic mechanisms.

Note that the referential identity imposed by coordination in examples like (7a) and (10a) is not shown in superficially parallel examples involving Right Node Raising. Compare the two examples in (11):

(11) a. John road-tested and bought a new Saab.
b. John bought but Bill only leased a new Saab.

Sentence (11a) is a straightforward example of coordination, imposing referential identity; the same car is involved in both actions. However, in (11b) two different cars may be involved. This suggests that there are two referential indices on *a new Saab* in (11b), which further implies two separate NP nodes in c-structure, supporting the deletion (or empty category) analysis of Right Node Raising proposed in Peterson (1988).

2.2 Anaphora

Further consequences of the distribution of grammatical functions via mechanism (6b) become evident when we consider patterns of anaphora. A reflexive pronoun in English may normally have either a subject or an object antecedent within a simple clause:

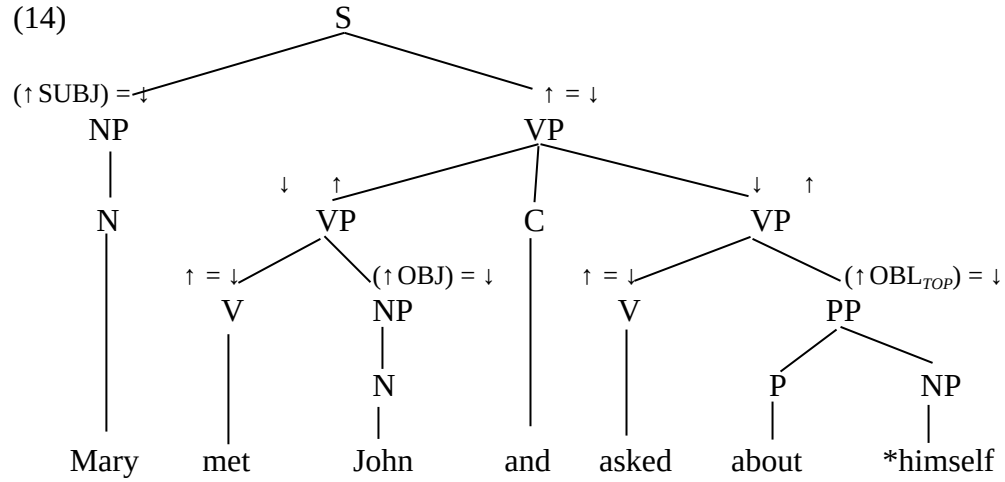
(12) Mary_i asked John_j about herself_i/himself_j.

However, (13) shows that an object within one of a pair of coordinate VPs is not a possible antecedent for a reflexive in the other coordinate VP:

(13) Mary_i met John_j and asked about herself_i/*himself_j.

This constraint on coreference falls out directly from the fact that subjects but not objects distribute across coordinated VPs; in other words the VPs share a subject but do not share an object. We can see how this property follows from our analysis by considering the structures associated with (13):

(14)



(15) f_1

$$\left\{ \begin{array}{ll} f_2 & \left[\begin{array}{ll} \text{SUBJ} & f_4 \text{ PRED 'Mary'} \\ \text{TENSE} & \text{PAST} \\ \text{PRED} & \text{'meet <}(f_2 \text{ SUBJ}) (f_2 \text{ OBJ})\text{>'} \\ \text{OBJ} & \text{PRED 'John'} \end{array} \right] \\ f_3 & \left[\begin{array}{ll} \text{SUBJ} & f_4 \\ \text{TENSE} & \text{PAST} \\ \text{PRED} & \text{'ask <}(f_3 \text{ SUBJ}) (f_3 \text{ OBL}_{TOP})\text{>'} \\ \text{OBL}_{TOP} & \left[\begin{array}{ll} \text{PRED} & \text{'PRO'} \\ \text{GEND} & \text{MASC} \\ \text{NCL} & + \end{array} \right] \end{array} \right] \end{array} \right\}$$

Since the VP is the functional head of S, the set f_1 in (15) which is the f-structure of VP is also the f-structure of S. Therefore the SUBJ attribute of the S f-structure (*Mary*) is distributed into the f-structures f_2 and f_3, as before. Consequently, the subject *Mary* is shared by both conjuncts. Now, a reflexive, or [+NCL], pronoun must be assigned an antecedent in its nucleus, the minimal f-structure containing the reflexive and a SUBJ (in this case f_3). Therefore the only possible antecedent available for the reflexive pronoun in (15) is *Mary*. *John* is not in the same nuclear f-structure as the reflexive. This explains the restrictions on the reflexives in (13).

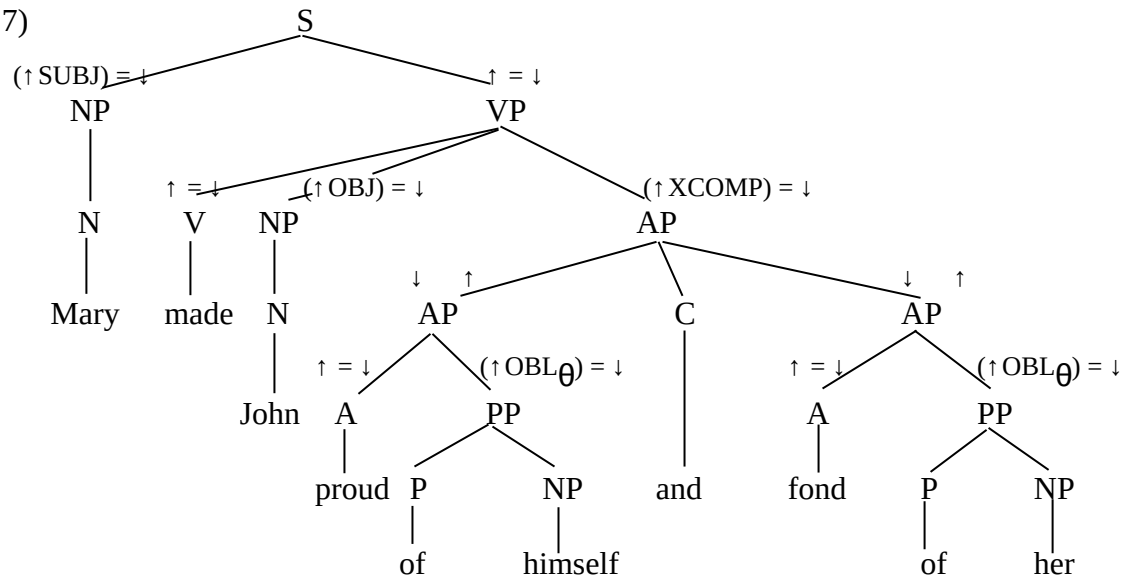
2.3 Control

The examples in (16) show that the distribution of grammatical functions across coordinated elements provided by schema (6b) also has direct implications for control phenomena.

(16) a. Mary$_i$ made John$_j$ proud of himself$_j$ and fond of her$_i$.
b. *Mary$_i$ made John$_j$ proud of him$_j$ and fond of herself$_i$.

Again, this pattern of anaphora is predicted by our analysis. Example (16a) has the c-structure shown in (17):

(17)



The coordinate AP *proud of himself and fond of her* is a complement of the V *make*, and bears the function of open complement (XCOMP), as shown in (18):

(18)

$$
f_0 \left[\begin{array}{ll}
\text{SUBJ} & f_4 \quad \text{PRED} \quad \text{‘Mary’} \\
\text{TENSE} & \text{PAST} \\
\text{PRED} & \text{‘make <}(f_0\,\text{SUBJ})\ (f_0\,\text{OBJ})\ (f_0\,\text{XCOMP})\text{>’} \\
\text{OBJ} & f_5 \quad \text{PRED} \quad \text{‘John’} \\
\text{XCOMP} & f_1 \left\{\begin{array}{l}
f_2 \left[\begin{array}{ll}
\text{SUBJ} & f_5 \\
\text{PRED} & \text{‘proud-of <}(f_2\ \text{SUBJ})\ (f_2\ \text{OBL}_\theta)\text{>’} \\
\text{OBL}_\theta & \left[\begin{array}{ll} \text{PRED} & \text{‘PRO’} \\ \text{GEND} & \text{MASC} \\ \text{NCL} & + \end{array}\right]
\end{array}\right] \\
f_3 \left[\begin{array}{ll}
\text{SUBJ} & f_5 \\
\text{PRED} & \text{‘fond-of <}(f_3\ \text{SUBJ})\ (f_3\ \text{OBL}_\theta)\text{>’} \\
\text{OBL}_\theta & \left[\begin{array}{ll} \text{PRED} & \text{‘PRO’} \\ \text{GEND} & \text{FEM} \\ \text{NCL} & - \end{array}\right]
\end{array}\right]
\end{array}\right.
\end{array}\right]
$$

In addition to the XCOMP, f_0 contains the OBJ f-structure (f_5) and the lexical features of the verb *made*. These features include TENSE, the PRED of *make*, and a lexically-induced functional control relation which identifies the object of *make* as the understood subject of its open complement (Bresnan 1982a). This relation is expressed by the control schema (19) which is a lexical property of the verb *make*:

(19) (↑ OBJ) = (↑ XCOMP SUBJ)

In the context of (18), this control schema is realised as (f_0 OBJ) = (f_0 XCOMP SUBJ); in other words, the OBJ of f_0 is to be identified as the SUBJ of the XCOMP of f_0. Since the XCOMP of f_0 is f_1, we have (f_0 OBJ) = (f_1 SUBJ). But f_1 is a set of f-structures, and so the

SUBJ relation distributes. Hence (f_1 SUBJ) = (f_2 SUBJ) = (f_3 SUBJ). Thus the value of f_0's OBJ must be included in both (f_2 SUBJ) and (f_3 SUBJ), as shown in (18).

Recall that the principles of bound anaphora require that the reflexive ([+NCL] pronoun must have an antecedent in its nucleus (in this case f_2). Conversely, the non-reflexive [-NCL] pronoun must not have an antecedent in its nucleus (f_3). In either case, the only potential antecedent is the subject, which has been identified with the object of the matrix verb (f_5, *John*). This explains the pattern of grammaticality in (16). In (16a), *John* must be the antecedent of *himself* and must not be the antecedent of *her*, while in (16b) *him* must not have *John* as an antecedent and *herself* must.

2.4 Coordination of "unlike categories"

We can now address the apparent problem posed by the coordination of unlike syntactic categories, first brought to our attention by Simon Dik (1968). The issue here is how to account for examples such as (20a) where the coordinated categories differ, while at the same time excluding examples such as (20b):

(20) a The children are tired and becoming restless.
b *John saw a unicorn and happy.

When we examine the f-structures for such sentences, the answer falls out from the mechanisms already established, in particular, distribution across sets provided by schema (6b) together with the theory of control. (We therefore do not need to call upon special mechanisms such as "Mother Feature Spread" which feature in structure-based accounts such as Sag et al (1985)). The f-structure for (20a) is represented in (21):

(21) f_0
$$\begin{bmatrix} \text{SUBJ} & f_4 & \begin{bmatrix} \text{PRED} & \text{'children'} \\ \text{NUM} & \text{PLU} \\ \text{DEF} & - \end{bmatrix} \\ \text{TENSE} & \text{PRES} & \\ \text{PRED} & \text{'be <}(f_0\ \text{SUBJ})\ (f_0\ \text{XCOMP})\text{>'} & \\ \text{XCOMP} & f_1 & \left\{ \begin{array}{l} f_2 \begin{bmatrix} \text{SUBJ} & f_4 \\ \text{PRED} & \text{'tired <}(f_2\ \text{SUBJ})\text{>'} \end{bmatrix} \\ f_3 \begin{bmatrix} \text{SUBJ} & f_4 \\ \text{PRED} & \text{'become <}(f_3\ \text{SUBJ})\ (f_3\ \text{XCOMP})\text{>'} \\ \text{XCOMP} & f_5 \begin{bmatrix} \text{SUBJ} & f_4 \\ \text{PRED} & \text{'restless <SUBJ>'} \end{bmatrix} \end{bmatrix} \end{array} \right\} \end{bmatrix}$$

The lexical entry for the verb *be* includes the functional control equation (22):

(22) $(\uparrow \text{XCOMP SUBJ}) = (\uparrow \text{SUBJ})$

i.e. the SUBJ of the complement of *be* is identified as the SUBJ of *be* itself.[3] Since the XCOMP in (21) is a set of f-structures, the SUBJ of XCOMP distributes to each member of the set, establishing *the children* as subject of the AP *tired* and also as subject of the VP *becoming restless*. Now consider the f-structure for (20b), as shown in (23):

23 f_0 [SUBJ f_4 PRED 'John'
TENSE PAST
PRED 'see <(f_0 SUBJ) (f_0 OBJ)>'
OBJ f_1 { f_2 [PRED 'unicorn'
DEF –]
f_3 [SUBJ (??)
PRED 'happy <(f_3 SUBJ)>'] }]

Here the problem with (20b) becomes immediately obvious. The lexical entry for *happy* specifies that it requires a subject. But no SUBJ is available for distribution into the OBJ set since the matrix verb *see* has no lexical control equation. Hence the f-structure for *happy* is incomplete. It is clear, then, that the coordination of unlike categories is not remarkable, because syntactic category membership is not the issue. It is grammatical function which determines the ability to coordinate. Nor is it mysterious that the coordination of unlike categories is only acceptable when the coordination serves as XCOMP or Adjunct. This is in fact a requirement of the theory, since only when the coordination is in a control relation can each functional sub-structure be locally complete.[4]

[3] This is couched in terms of the "main verb" analysis of auxiliary verbs such as *be* (see discussion in Huddleston & Pullum (in press)). The argument follows through, *mutatis mutandis*, under the analysis of auxiliaries as belonging to the functional category I, head of IP, as in Bresnan (2001).

[4] The unacceptable coordination accounted for in (23) is the coordination of NP (*a unicorn*) and AP (*happy*). A different account is required for the coordination of VPs, [*saw a unicorn*] and [*happy*]. In English this fails because the adjective *happy* requires a controlling copular verb. In Bahasa Indonesia the coordination of VPs succeeds, as shown in (i):

(i) John melihat kuda putih itu dan senang.
name see horse white that and happy
'John saw the white horse and (was) happy'

because *senang* can be a free-standing predicate. My thanks to an anonymous reviewer for drawing my attention to this fact.

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